The Influence of the Shallow Water Internal Tide on the Properties of Acoustic Signals

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LONG-TERM GOAL

Quantitatively relate the temporal and spatial properties of shallow water acoustic signals to the physical processes that cause variability in the shallow water sound speed field. Address tides, internal tides, internal waves, fine structure, surface gravity wavefields and the heterogeneous ocean bottom/subbottom.

SCIENTIFIC OBJECTIVES

Increase the understanding of the physics of broadband acoustic signal propagation through the random shallow water waveguide. Develop an ability to predict or estimate the coherence properties of acoustic signals propagating in shallow water.

APPROACH

Simultaneous measurement of the spatial and temporal properties of acoustic signals and the sound speed field as perturbed by a variety of flow induced fluid processes. Numerical simulation of the hydrodynamic perturbation of the sound speed field and the acoustic signals that propagate through it. The FY02 year was primarily devoted to the initial analysis of the ONR FY01 AsiaEx South China Sea Ocean Research III environmental data. In addition, analysis of the SWARM95 environmental data set acquired on the New Jersey Shelf during the 2000 SWAT experiment was continued. The SWAT and SWARM data sets allow differences between fall and summer time propagation conditions to be studied and are being analyzed in preparation for an experiment to be conducted in the latter part of FY03.

WORK COMPLETED

ASIAEX (South China Sea)

Acoustic flow visualization, tow-yo CTD, ADCP and X-band radar data taken aboard the Ocean Researcher III during May 7 and 8, 2002 has been analyzed with the objective of determining how the dominant fluid processes in the experiment area controlled the sound speed field. Attention has been

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Quantitatively relate the temporal and spatial properties of shallow water acoustic signals to the physical processes that cause variability in the shallow water sound speed field. Address tides, internal tides, internal waves, fine structure, surface gravity wavefields and the heterogeneous ocean bottom/subbottom.

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focused on understanding how upslope propagating internal soliton packets evolve and cause sound speed field variability in the vicinity of the cross slope acoustic propagation path. The depression soliton wave packets, Figure 1, have been observed to convert to elevation solitons in water depths ranging from 260-120 m. Shear instabilities with scales of 40 m in the vertical and 100 m in the horizontal were observed suggesting that fine structure can be expected to impact acoustic signal coherence. Soliton packet dissipation rates have been extracted. A two-layer model of the water column has been constructed. Soliton depression to elevation perturbation of a range dependent sound speed field was calculated using an evolution equation representation of a single nonlinear soliton. The impact of the evolving soliton field on a matched field processor was quantified.

SWAT (New Jersey Shelf)

The ONR/NRL SWAT experiment from September 28 – October 4, 2000 acquired a unique environmental data set including scanfish and acoustic flow visualization data. The data set revealed the presence of mode 1 and 2 internal waves as well as intermittent shear instability along a 10-20 km acoustic signal propagation path. Due to the persistent presence of the shear instabilities an experiment is planned in FY03 with the objective of quantify the impact of the shear instabilities on acoustics signal horizontal coherence in the 100-1000 Hz frequency band. As part of the preparation for the FY03 experiment the SWAT data is being analyzed to establish the location, lateral extent, frequency of occurrence and relationship of the shear instabilities to the tide and or atmospheric wind stress.

RESULTS

ASIAEX

The depression to elevation conversion of upslope propagating soliton packets has been studied. First attempts to understand their influence on acoustic signal properties and phase coherent signal processors have been made. Dissipation rates have been extracted from the data.

SWAT

The locations and lateral extent of shear instabilities are being identified and are being used in the design of a FY03 shallow water propagation experiment.

SWARM

Range dependent sound speed fields have been reconstructed for the same time interval that acoustic propagation data was taken. The sound speed field represents a convolution of tow-yo CTD data and acoustic flow visualization data. Long-term trends in the depth averaged measured acoustic field are being compared to the depth averaged acoustic field calculated using the reconstructed sound speed field.

IMPACT/APPLICATIONS

In the long term, the results of this work will permit the prediction of ASW system performance in a shallow water propagation channels that have sound speed fields properties controlled by tidally related fluid processes.

TRANSITIONS

None

RELATED PROJECTS

The ASIAEX, SWARM and SWAT efforts are interdisciplinary and included a number of ONR supported scientists including members of the Woods Hole Oceanographic Institution, the Naval Postgraduate School, The University of Miami and the University of Maine.

PUBLICATIONS

Referred Articles

Orr, M. H. and Mignerey, P. C., 2002, Matched Field Processing Gain Degradation Caused by Tidal Flow Over Continental Shelf Bathymetry, J. Acoust. Soc. Am., 111, 2615-2620.

Rouseff, D., Turgut, A., Wolf, S. N., Finette, S., Orr, M. H., Pasewark, B. H., Apel, J., Badiey, M., Chiu, C., Headrick, R. H., Lynch, J. F., Kemp, J. N., Newhall, A. E., von der Heydt, K., Tielbuerger, D., 2002, Coherence of acoustic modes propagating through shallow water internal waves, J. Acoust. Soc. Am., 111, 1655-1666.

Orr, M. H. and Mignerey, P. C., 2002, Nonlinear internal waves in the South China Sea – observation of the conversion of depression internal waves to elevation internal waves, J. Geophys. Res., accepted.

Papers

Mignerey, P. C. and Orr, M. H., 2002, Depth averaged acoustic field variability – its relationship to sound speed field variability – comparison of SWARM data to PE simulations, J. Acoust. Soc. Am., 111, pg. 2459A.

Orr, M. H., 2001, Observation of small-scale fluid processes in the vicinity of continental shelf breaks using high-frequency acoustic backscattering systems, J. Acoust. Soc. Am., 110, pg 2641A.

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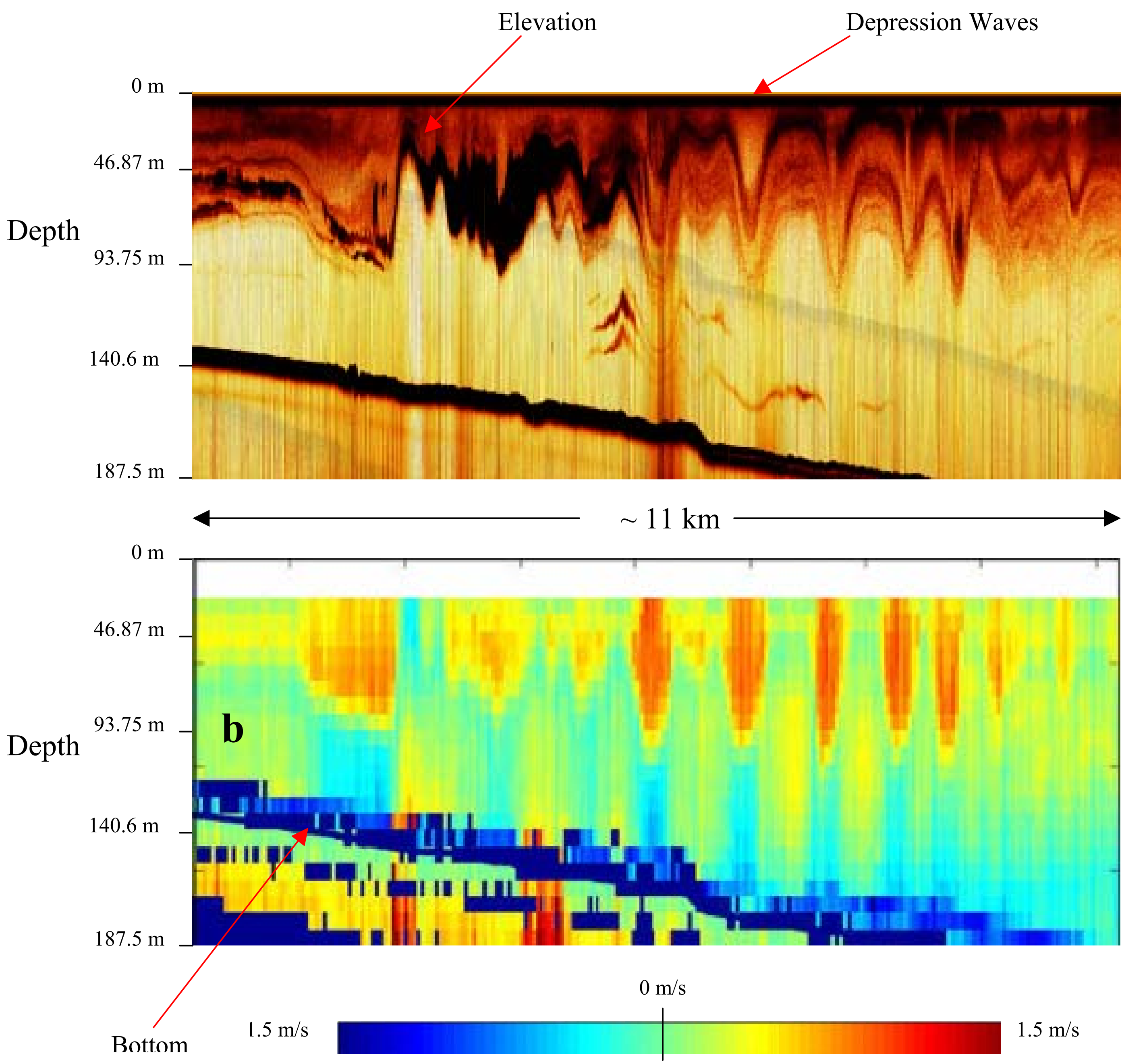

Figure 1. a) A nonlinear internal soliton packet propagating up the South China Sea slope. Depression to elevation wave conversion is seen in the ~ 140 m water depth. The wave packet is perturbing an 11 km horizontal section of the sound speed field. Scattering layers are being displaced by ~ 70 m. The sound speed field is undergoing the same vertical displacement.; b) Upslope and downslope currents extracted for shipboard ADCP data. Note change in current direction as the ship went from elevation waves to depression solitons. Currents are > 1.0 m/s. Currents within ~ 10 m of the bottom are not accurate. The upslope propagation speed of the internal wave packet was 1.17 m/s.